reproduction has taken place in their ancestry being at the same time reduced to a minimum.

On the contrary, we must expect that a much smaller number of ancestors lies between the lower-developed groups and the common parent form, that a-sexual reproduction has here more repeatedly occurred, and that finally, Darwin's and Huxley's explanation, which we have above alluded to, of the non-occurrence of further modifications, may here have been realised to a greater extent.

Keeping in view the combined action of both these principles, we no longer wonder that even in the present day living representatives are found of genera which were already present in the Silurian epoch, nor that the simplest organised beings have continued to exist in that primitive form.

They are for the greater part the younger sons, and being condemned to a slower rate of development, they could not keep apace of their elder brothers. The latter, which have so much oftener passed through the improving crucible of sexual reproduction, are indebted to that cause for having become the parent stock out of which the higher and highest-developed animal and vegetable forms, now surrounding us, have gradually sprung.

THE ETHER AND ITS FUNCTIONS [1]

I HOPE that no one has been misled by an error in the printing of the title of this lecture, viz. the omission of the definite article before the word ether, into supposing that I am going to discourse on chemistry and the latest anæsthetic; you will have understood, I hope, that "ether" meant *the* ether, and that the ether is the hypothetical medium which is supposed to fill otherwise empty space.

The idea of an ether is by no means a new one. As soon as a notion of the enormous extent of space had been grasped, by means of astronomical discoveries, the question presented itself to men's minds, what was in this space? was it full, or was it empty? and the question was differently answered by different metaphysicians. Some felt that a vacuum was so abhorrent a thing that it could not by any possibility exist anywhere, but that nature would not be satisfied unless space were perfectly full. Others, again, felt that *empty* space could hardly exist, that it would shrink up to nothing like a pricked bladder unless it were kept distended by something material. In other words, they made matter the condition of extension. On the other hand, it was contended that however objectionable the idea of empty space might be, yet emptiness was a necessity in order that bodies might have room to move; that, in fact, if all space were perfectly full of matter everything would be jammed together, and nothing like free attraction or free motion of bodies round one another could go on.

And indeed there are not wanting philosophers at the present day who still believe something of this same kind, who are satisfied to think of matter as consisting of detached small particles acting on one another with forces varying as some inverse power of the distance, and who, if they can account for a phenomenon by an action exerted across empty space, are content to go no further, nor seek the cause and nature of the action more closely.[2]

Now metaphysical arguments, in so far as they have any weight or validity whatever, are unconscious appeals to experience; a person endeavours to find out whether a certain condition of things is by him conceivable, and if it is not conceivable he has some *primâ facie* ground for asserting that it probably does not exist. I say he has *some* ground, but whether it be much or little depends partly on the nature of the thing thought of, whether it be fairly simple or highly complex, and partly on the range of the man's own mental development, whether his experience be wide or narrow.

If a highly-developed mind, or set of minds, find a doctrine about some comparatively simple and fundamental matter absolutely unthinkable, it is an evidence, and it is accepted as good evidence, that the unthinkable state of things is one that has no existence; the argument being that if it did exist, either it or something not wholly unlike it would have come within the range of experience. We have no further evidence than this for the statement that two straight lines cannot inclose a space, or that the three angles of a triangle are equal to two right angles.

[1] A lecture by Prof. Oliver Lodge at the London Institution, on December 28, 1882.

[2] In illustration of this statement an article has since appeared in the January number of the *Philosophical Magazine*, by Mr. Walter Browne.

Nevertheless there is nothing final about such an argument; all that the inconceivability of a thing really proves, or can prove, is that nothing like it has ever come within the thinker's experience; and this proves nothing as to the reality or non-reality of the thing, unless his experience of the same kind of things has been so extensive as to make it reasonably probable that if such a thing had existed it would not have been so completely overlooked.

The experience of a child or a dog, on ordinary scientific phenomena, therefore, is worth next to nothing; and as the experience of a dog is to ordinary science, so is the experience of the human race to some higher phenomena, of which they at present know nothing, and against the existence of which it is perfectly futile and presumptuous to bring forward arguments about their being inconceivable, as if they were likely to be anything else.

Now if there is one thing with which the human race has been more conversant from time immemorial than another, and concerning which more experience has been unconsciously accumulated than about almost anything else that can be mentioned, it is *the action of one body on another;* the exertion of force by one body upon another, the transfer of motion and energy from one body to another; any kind of effect, no matter what, which can be produced in one body by means of another, whether the bodies be animate or inanimate. The action of a man in felling a tree, in thrusting a spear, in drawing a bow; the action of the bow again on the arrow, of powder on a bullet, of a horse on a cart; and again, the action of the earth on the moon, or of a magnet on iron. Every activity of every kind that we are conscious of may be taken as an illustration of the action of one body on another.

Now I wish to appeal to this mass of experience, and to ask, is not the direct action of one body on another across empty space, and with no means of communication whatever, is not this absolutely unthinkable? We must not answer the question offhand, but must give it due consideration, and we shall find, I think, that wherever one body acts on another by obvious contact, we are satisfied and have a feeling that the phenomenon is simple and intelligible; but that whenever one body apparently acts on another at a distance, we are irresistibly impelled to look for the connecting medium.

If a marionette dances in obedience to a prompting hand above it, any intelligent child would feel for the wire, and if no wire or anything corresponding to it were discovered, would feel that there was something uncanny and magical about the whole thing. Ancient attempts at magic were indeed attempts to obtain results without the trouble of properly causing them, to build palaces by rubbing rings or lanterns, to remove mountains by a wish instead of with the spade and pickaxe, and generally to act on bodies without any real means of communication; and modern disbelief in magic is simply a statement of the conviction of mankind that all attempts in this direction have turned out failures, and that action at a distance is impossible.

If a man explained the action of a horse or a cart by saying that there was an attraction between them varying as some high direct power of the distance, he would not be saying other than the truth—the facts may be so expressed—but he would be felt to be giving a wretchedly lame explanation, and any one who simply pointed out the traces would be going much more to the root of the matter. Similarly with the attraction of a magnet for another magnetic pole. To say that there is an attraction as the inverse cube of the distance between them is true, but it is not the whole truth; and we should be obliged to any one who will point out the traces, for traces we feel sure there are. If any one tries to picture clearly to himself the action of one body on another without any medium of communication whatever, he must fail. A medium is instinctively looked for in most cases, and if not in all, as in falling weights or in magnetic attraction, it is only because custom has made us stupidly callous to the real nature of these forces.

When we see a vehicle bowling down-hill without any visible propelling force we ought to regard it with the same mixture of curiosity and wonder as the Chinaman felt when he saw for the first time in the streets of Philadelphia a tram-car driven by a rope buried in a pipe underground. The attachment to these cars comes through a narrow slit in the pipe, and is quite unobtrusive. After regarding the car with open-mouthed astonishment for some time, the Chinaman made use of the following memorable exclamation, "No pushee—No pullee—Go like mad!" He was a philosophic Chinaman.

Remember then that whenever we see a thing being moved we must look for the rope; it may be visible or it may be invisible, but unless there is either "pushee" or "pullee" there can be no action. And if you further consider a pull it revolves itself into a push; to pull a thing towards you, you have to put your finger behind it and push; a horse is said to pull a cart, but he is really pushing at the collar; an engine pushes a truck by means of a hook and eye; and so on. There is still the further very important and difficult question as to why the parts hang together, and why when you push one part the rest follows.

Cohesion is a very striking fact, and an explanation of it is much to be desired; I shall have a little more to say about it later, but at present we have nothing more than an indication of the direction in which an explanation seems possible. We cannot speak distinctly about those actions which are as yet mysterious to us, but concerning those which are comparatively simple and intelligible we may make this general statement:—The only way of acting on a body directly is to push it behind.

There must be contact between bodies before they can directly act on each other; and if they are not in contact with each other and yet act, they must both be in contact with some third body which is the medium of communication, the rope.

Consider now for an instant the most complex case, the action of one animate body on another not touching it. To call the attention of a dog, for instance, there are several methods: one plan is to prod him with a stick, another is to heave a stone at him, a third is to whistle or call, while a fourth is to beckon him by gesture, or, what is essentially the same process, to flash sunlight into his eye with a mirror. In the first two of these methods the media of communication are perfectly obvious—the stick and the stone—in the third, the whistle, the medium is not so obvious, and this case might easily seem to a savage like action at a distance, but we know of course that it is the air, and that if the air between be taken away, all communication by sound is interrupted. But the fourth or optical method is not so interrupted; the dog can see through a vacuum perfectly well, though he cannot hear through it; but what the medium now is which conveys the impression is not so well known. The sun's light is conveyed to the earth by such a medium as this across the emptiness of planetary space. The only remaining typical plans of acting on the dog would be either by electric or magnetic attractions, or by mesmerism, and I would have you seek for the medium which conveys these impressions with just as great a certainty that there is one as in any of the other cases.

Leaving these more mysterious and subtle modes of communication, let us return to the two most simple ones, viz., the stick and the stone. These two are representative of the only possible fundamental modes of communication between distant bodies, for one is compelled to believe that every more occult mode of action will ultimately resolve itself into one or other of these two.

The stick represents the method of communication by continuous substance; the stone represents the communication by actual transfer of matter, or, as I shall call it, the projectile method. There are no other known methods for one body to act on another than by these two—by continuous medium and by projectile.

We know one clear and well-established example of the projectile method, viz., the transmission of pressure by gases. A gas consists of particles perfectly independent of each other, and the only way in which they can act on each other is by blows. The pressure of the air is a bombardment of particles, and actions are transmitted through gases as through a row of ivory balls. Sound is propagated by each particle receiving a knock and passing it on to the next, the final effect being much the same as if the first struck particles had been shot off through the whole distance.

The explanation of the whole behaviour of gases in this manner is so simple and satisfactory, and moreover is so certainly the true account of the matter, that we are naturally tempted to ask whether this projectile theory is not the key to the universe, and whether every kind of action whatever cannot be worked out on this hypothesis of atoms blindly driving about in all directions at perfect random and with complete independence of each other except when they collide.[1] And accordingly we have the corpuscular theories of light and of gravitation; both account for the respective phenomena by a battering of particles. The corpuscular theory of gravitation is, however, full of difficulties, for it is not obvious according to it why the weight of a plate is the same when held edgeways as when held broadside on, in the stream of corpuscles; while it is surprising (as indeed it perhaps is on any hypothesis) that the weight of a body is the same in the solid, liquid, and gaseous states. It has been attempted to explain cohesion also on the same hypothesis, but the difficulties, which were great enough before, are now enormous, and to me at any rate it seems that it is only by violent straining and by improbable hypotheses that we can explain all the actions of the universe by a mere battery of particles.

Moreover, it is difficult to understand what the atoms themselves can be like, or how they can strike and bound off one another without yielding to compression and then springing out again like two elastic balls; it is difficult to understand the elasticity of really ultimate hard particles. And if the atoms are not such hard particles, but are elastic and yielding, and bound from one another according to the same sort of law that ivory balls do, of what are they composed? We shall have to begin all over again, and explain the cohesion and elasticity of the parts of the atom.

The more we think over the matter, the more are we compelled to abandon mere impact as a complete explanation of action in general. But if this be so we are driven back upon the other hypothesis, the only other, viz. communication by continuous medium.

We must begin to imagine a continuous connecting medium between the particles—a substance in which they are imbedded, and which extends into all their interstices, and extends without break to the remotest limits of space. Once grant this and difficulties begin rapidly to disappear. There is now continuous contact between the particles of bodies, and if one is pushed the others naturally receive the motion. The atoms of gas are impinging as before, but we have now a different idea of what impact means.

Gravitation is explainable by differences of pressure in the medium, caused by some action between it and matter not yet understood. Cohesion is explainable also probably in the same way.

Light consists of undulation or waves in the medium; while electricity is turning out quite possibly to be an aspect of a part of the very medium itself.

The medium is now accepted as a necessity by all modern physicists, for without it we are groping in the dark, with it we feel we have a clue which, if followed up, may lead us into the innermost secrets of nature. It has as yet been followed up very partially, but I will try and indicate the directions in which modern science is tending.

The name you choose to give to the medium is a matter of very small importance, but "the Ether" is as good a name for it as another.

As far as we know it appears to be a perfectly homogeneous incompressible continuous body incapable of being resolved into simple elements or atoms; it is, in fact, continuous, not molecular. There is no other body of which we can say this, and hence the properties of ether must be somewhat different from those of ordinary matter. But there is little difficulty in picturing a continuous substance to ourselves, inasmuch as the molecular and porous nature of ordinary matter is by no means evident to the senses, but is an inference of some difficulty.

Ether is often called a fluid, or a liquid, and again it has been called a solid and has been likened to a jelly because of its rigidity; but none of these names are very much good; all these are molecular groupings, and therefore not like ether; let us think simply and solely of a continuous frictionless medium possessing inertia, and the vagueness of the notion will be nothing more than is proper in the present state of our knowledge.

We have now to try and realise the idea of a perfectly continuous, subtle, incompressible substance pervading all space and penetrating between the molecules of all ordinary matter, which are imbedded in it, and connected with one another by its means. And we must regard it as the one universal medium by which all actions between bodies are carried on. This, then, is its function—to act as the transmitter of motion and of energy. First consider the propagation of light.

Sound is propagated by direct excursion and impact of the atoms of ordinary matter. Light is not so propagated. How do we know this?

1. Because of speed, 3×10^{10}, which is greater than anything transmissible by ordinary matter.

2. Because of the kind of vibration, as revealed by the phenomena of polarisation.

[1] To this hypothesis Mr. Tolver Preston has addressed himself with much ingenuity.

The vibrations of light are not such as can be transmitted by a set of disconnected molecules; if by molecules at all, it must be by molecules connected into a solid, *i.e.* by a body with rigidity. Rigidity means active resistance to shearing stress, *i.e.* to alteration in shape; it is also called *elasticity of figure;* it is by the possession of rigidity that a solid differs from a fluid. For a body to transmit vibrations at all it must possess inertia; transverse vibrations can only be transmitted by a body with rigidity. All matter possesses inertia, but fluids only possess volume elasticity, and accordingly can only transmit longitudinal vibrations. Light consists of transverse vibrations; air and water have no rigidity, yet they are transparent, *i.e.* transmit transverse vibrations; hence it must be the ether inside them which really conveys the motion, and the ether must have properties which, if it were ordinary matter, we should style *inertia* and *rigidity*. No highly rarefied air will serve the purpose; the ether must be a distinct body. Air *exists* indeed in planetary space even to infinity, but it is of almost infinitesimal density compared with the ether there. It is easy to calculate the density of the atmosphere at any height above the earth's surface, supposing other bodies absent.

The density of the air at a distance of n earth radii from the centre of the earth is equal to a quarter the density here divided by $10^{350\frac{n-1}{n}}$. So at a height of only 4000 miles above the surface, the atmospheric density is a number with 127 ciphers after the decimal point before the significant figures begin. The density of ether, on the other hand, has been calculated by Sir William Thomson from data furnished by Pouillet's experiments on the energy of sunlight, and from a justifiable guess as to the amplitude of a vibration, and it comes out about 10^{-18}, a number with only 17 ciphers before the significant figures. In inter-planetary space, therefore, all the air that exists is utterly negligible; the density of the ether there, though small, is enormous by comparison.

Once given the density of the ether, its rigidity follows at once, because the ratio of the rigidity to the density is the square of the velocity of transverse wave propagation, viz. in the case of ether, 9×10^{20}. The rigidity of ether comes out, therefore, to be about 900. The most rigid solid we know is steel, and compared with its rigidity, viz. 8×10^{11}, that of ether is insignificant. Neither steel nor glass, however, could transmit vibrations with anything like the speed of light, because of their great density. The rate at which transverse vibrations are propagated by crown glass is half a million centimetres per second—a considerable speed, no doubt, but the ether inside the glass transmits them 40,000 times as quick, viz. at twenty thousand million centimetres per second.

The ether outside the glass can do still better than this, it comes up to thirty thousand million, and the question arises what is the matter with the ether inside the glass that it can only transmit undulations at two-thirds the normal speed. Is it denser than free ether, or is it less rigid? Well, it is not easy to say; but the fact is certain that ether is somehow affected by the immediate neighbourhood of gross matter, and it appears to be concentrated inside it to an extent depending on the density of the matter. Fresnel's hypothesis is that the ether is really denser inside gross matter, that there is a sort of attraction between ether and the molecules of matter which results in an agglomeration or binding of some ether round each atom, and that this additional or bound ether belongs to the matter, and travels about with it. The *rigiaity* of the bound ether Fresnel supposes to be the same as that of the free.

If anything like this can be imagined, a measure of the density of the bound ether is easily given. For the inverse velocity-ratio is called μ (the index of refraction), and the density is inversely as the square of the velocity, hence the density-measure is μ^2. The density of ether in free space being called 1, that inside matter has a density μ^2, and the density of the bound portion of this is $\mu^2 - 1$.

This may all sound very fanciful, but something like it is sober truth; not as it is here stated very likely, but the fact that $\left(1 - \frac{1}{\mu^2}\right)$th of the whole ether inside matter is bound to it and travels with it, while the remaining $\frac{1}{\mu^2}$th is free and blows freely through the pores, is fairly well established and confirmed by direct experiment.

(*To be continued.*)

UNIVERSITY AND EDUCATIONAL INTELLIGENCE

CAMBRIDGE.—The following further announcements of lectures have been made:—

Prof. Humphry, Circulatory and Respiratory Systems, Jan. 25; senior class, Jan. 29; Demonstrations by the Demonstrator for Natural Science Tripos, Jan. 26; Osteology, for beginners, Jan. 17; Demonstrations for second year students, Jan. 18; Mr. McAlister will give six lectures later in the term, on the Mechanism of the Human Skeleton. Dr. Michael Foster's course of Elementary Physiology, Jan. 23; Mr. Lea, Chemical Physiology, Jan. 24; Dr. Vines, Anatomy of Plants, advanced, with practical work, Jan. 24 (Christ's College); General Elementary course, New Museums, Jan. 23, to extend over two terms, and be illustrated by demonstrations. A class for the practical study of systematic botany, Mr. T. H. Corry, assistant curator of the Herbarium, will be formed. Dr. Hicks will lecture on the Morphology of Flowering Plants, with especial reference to classification, including floral diagrams, in the Hall of Sidney College, beginning Jan. 26; Mr. Glazebrook, advanced Demonstrations in Electricity and Magnetism, Cavendish Laboratory, Jan. 24; Mr. Shaw, Demonstrations in Mechanics and Heat, Jan. 23; if more students attend than can be accommodated in the laboratory at one time, the course will be repeated on the same days. Mr. Trotter, Trinity College, Physical Optics, Jan. 25. Mr. Pattison Muir, Non-metallic Elements, Elementary, Jan. 22, Caius College Laboratory; General Principles of Chemistry, Advanced, Jan. 23. Mr. Solly will give Demonstrations on Minerals in the Lecture Room of the Mineralogical Museum, first lecture, Jan. 22. Prof. Stuart, Jacksonian Lecture Room, Theory of Structures, Jan. 30; the Demonstrator of Mechanism, Mathematics required for Engineering, Jan. 29.

Christ's College Open Scholarships, Natural Science; E. L. Sortain, Bath College, 30*l.*; 3rd year, J. C. Bose, 30*l.*; Caius College, Natural Science, Edgworth, Clifton College, 40*l.*

MR. MARSHALL WARD is giving a course of free public lectures at Owens College, on the Nutrition of Plants.

SCIENTIFIC SERIALS

Journal of the Franklin Institute, January.—Electric lighting in mills, by C. J. H. Woodbury.—Bricks and brick-making machinery, by C. Chambers, Jun.—Experiential principles of controlled combustion, by E. J. Mallett, Jun.—Olsen's testing machines.

Archives des Sciences Physiques et Naturelles, December 15, 1882.—Meteorological *résumé* of the year 1881 for Geneva and the great St. Bernard, by A. Kammermann.—Observations on cometary refraction, by W. Meyer.—Development of the vegetable kingdom in different regions since the tertiary epoch, according to Dr. Engler's work, by A. de Candolle.—Periodical movements of the air indicated by spirit levels, by Ph. Plantamour.—On the same, by C. von Orff.

SOCIETIES AND ACADEMIES

LONDON

Chemical Society, January 18.—Dr. Gilbert, president, in the chair.—It was announced that a ballot for the election of fellows would be held at the next meeting, February 1.—The following papers were read:—The fluorine compounds of uranium, by A. Smithells. The author has investigated the action of aqueous hydrofluoric acid upon the green uranoso-uranic oxide. He finds that a voluminous green powder, uranium tetrafluoride, is left, and that a yellow solution is formed which contains uranium oxyfluoride. The author confirms the results previously obtained by Bolton, and proves those obtained by Ditte to be erroneous.—On a new method of estimating the halogens in volatile organic compounds, by R. T. Plimpton and E. E. Graves. The authors burn the vapour of the compound in a glass Bunsen burner, the products of the combustion are aspirated through caustic soda solution, which is heated with sulphurous acid and the halogen precipitated by silver nitrate, &c., in the usual way. Good results were obtained with various liquids from ethyl bromide boiling at 39° to acetylene bromiodide boiling at 150°.—On a modified Liebig's condenser, by W. A. Shenstone. The author has slightly modified a vertical con